Database-Connection Libraries

Call-Level Interface

Java Database Connectivity

PHP

An Aside: SQL Injection

- SQL queries are often constructed by programs.
- These queries may take constants from user input.
- Careless code can allow rather unexpected queries to be constructed and executed.

Example: SQL Injection

- Relation Accounts(name, passwd, acct).
- Web interface: get name and password from user, store in strings *n* and *p*, issue query, display account number.

```
SELECT acct FROM Accounts
WHERE name = :n AND passwd = :p
```

User (Who Is Not Bill Gates) Types

Comment in Oracle

Name: `gates'`

Password: `who cares?`

Your account number is 1234-567

The Query Executed

```
SELECT acct FROM Accounts
WHERE name = 'gates'  --' AND
passwd = 'who cares?'
```

All treated as a comment

Host/SQL Interfaces Via Libraries

- The third approach to connecting databases to conventional languages is to use library calls.
  1. C + CLI
  2. Java + JDBC
  3. PHP + PEAR/DB

Three-Tier Architecture

- A common environment for using a database has three tiers of processors:
  1. *Web servers* --- talk to the user.
  2. *Application servers* --- execute the business logic.
  3. *Database servers* --- get what the app servers need from the database.

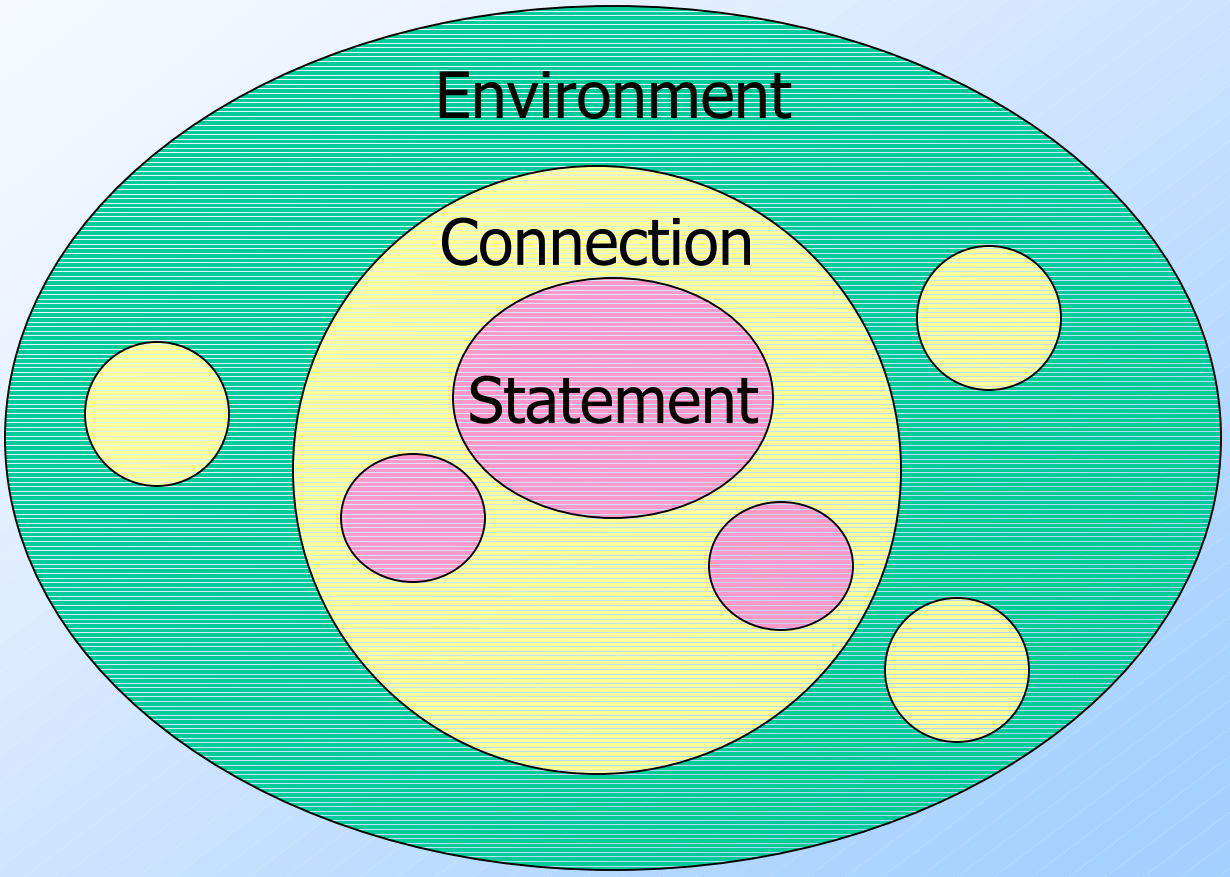
Example: Amazon

- Database holds the information about products, customers, etc.
- Business logic includes things like "what do I do after someone clicks 'checkout'?"
  - Answer: Show the "how will you pay for this?" screen.

Environments, Connections, Queries

- The database is, in many DB-access languages, an *environment*.
- Database servers maintain some number of *connections*, so app servers can ask queries or perform modifications.
- The app server issues *statements* : queries and modifications, usually.

Diagram to Remember



SQL/CLI

- Instead of using a preprocessor (as in embedded SQL), we can use a library of functions.
  - The library for C is called SQL/CLI = "*Call-Level Interface*."
  - Embedded SQL's preprocessor will translate the EXEC SQL … statements into CLI or similar calls, anyway.

Data Structures

- C connects to the database by structs of the following types:
  1. *Environments* : represent the DBMS installation.
  2. *Connections* : logins to the database.
  3. *Statements* : SQL statements to be passed to a connection.
  4. *Descriptions* : records about tuples from a query, or parameters of a statement.

Handles

- Function SQLAllocHandle(T,I,O) is used to create these structs, which are called environment, connection, and statement *handles*.
  - *T* = type, e.g., SQL_HANDLE_STMT.
  - *I* = input handle = struct at next higher level (statement < connection < environment).
  - *O* = (address of) output handle.

Example: SQLAllocHandle

```
SQLAllocHandle(SQL_HANDLE_STMT,
  myCon, &myStat);
```

- `myCon` is a previously created connection handle.
- `myStat` is the name of the statement handle that will be created.

Preparing and Executing

- SQLPrepare(H, S, L) causes the string *S*, of length *L*, to be interpreted as a SQL statement and optimized; the executable statement is placed in statement handle *H*.
- SQLExecute(H) causes the SQL statement represented by statement handle *H* to be executed.

Example: Prepare and Execute

```
SQLPrepare(myStat, "SELECT
  beer, price FROM Sells
  WHERE bar = 'Joe''s Bar'",
  SQL_NTS);
SQLExecute(myStat);
```

This constant says the second argument is a "null-terminated string"; i.e., figure out the length by counting characters.

Direct Execution

- If we shall execute a statement *S* only once, we can combine PREPARE and EXECUTE with:

SQLExecuteDirect(H,S,L);

  - As before, *H* is a statement handle and *L* is the length of string *S*.

Fetching Tuples

- When the SQL statement executed is a query, we need to fetch the tuples of the result.
  - A cursor is implied by the fact we executed a query; the cursor need not be declared.
- SQLFetch(H) gets the next tuple from the result of the statement with handle *H*.

Accessing Query Results

- When we fetch a tuple, we need to put the components somewhere.
- Each component is bound to a variable by the function SQLBindCol.
  - This function has 6 arguments, of which we shall show only 1, 2, and 4:

    1 = handle of the query statement.

    2 = column number.

    4 = address of the variable.

Example: Binding

- Suppose we have just done SQLExecute(myStat), where myStat is the handle for query

```
SELECT beer, price FROM Sells
WHERE bar = 'Joe''s Bar'
```

- Bind the result to theBeer and thePrice:

```
SQLBindCol(myStat, 1, , &theBeer, , );
SQLBindCol(myStat, 2, , &thePrice, , );
```

Example: Fetching

- Now, we can fetch all the tuples of the answer by:

```
while ( SQLFetch(myStat) != SQL_NO_DATA)
  {
      /* do something with theBeer and
         thePrice */
  }
```

CLI macro representing SQLSTATE = 02000 = "failed to find a tuple."

JDBC

- *Java Database Connectivity* (JDBC) is a library similar to SQL/CLI, but with Java as the host language.
- Like CLI, but with a few differences for us to cover.

Making a Connection

```
import java.sql.*;
Class.forName(com.mysql.jdbc.Driver);
Connection myCon =
  DriverManager.getConnection();
```

The JDBC classes

Loaded by forName

URL of the database your name, and password go here.

The driver for mySql; others exist

Statements

- JDBC provides two classes:
  1. *Statement* = an object that can accept a string that is a SQL statement and can execute such a string.
  2. *PreparedStatement* = an object that has an associated SQL statement ready to execute.

Creating Statements

- The Connection class has methods to create Statements and PreparedStatements.

```
Statement stat1 = myCon.createStatement();
PreparedStatement stat2 =
   myCon.createStatement(
      "SELECT beer, price FROM Sells " +
      "WHERE bar = 'Joe' 's Bar' "
   );
```

createStatement with no argument returns a Statement; with one argument it returns a PreparedStatement.

Executing SQL Statements

- JDBC distinguishes queries from modifications, which it calls "updates."
- Statement and PreparedStatement each have methods executeQuery and executeUpdate.
  - For Statements: one argument: the query or modification to be executed.
  - For PreparedStatements: no argument.

Example: Update

- stat1 is a Statement.
- We can use it to insert a tuple as:

```
stat1.executeUpdate(
  ”INSERT INTO Sells ” +
  ”VALUES(’Brass Rail’,’Bud’,3.00)”
);
```

Example: Query

- stat2 is a PreparedStatement holding the query ”SELECT beer, price FROM Sells WHERE bar = ’Joe”s Bar’ ”.
- executeQuery returns an object of class ResultSet – we’ll examine it later.
- The query:

```
ResultSet menu = stat2.executeQuery();
```

Accessing the ResultSet

- An object of type ResultSet is something like a cursor.
- Method next() advances the "cursor" to the next tuple.
  - The first time next() is applied, it gets the first tuple.
  - If there are no more tuples, next() returns the value false.

Accessing Components of Tuples

- When a ResultSet is referring to a tuple, we can get the components of that tuple by applying certain methods to the ResultSet.
- Method get*X*(*i*), where *X* is some type, and *i* is the component number, returns the value of that component.
  - The value must have type *X*.

Example: Accessing Components

- Menu = ResultSet for query "SELECT beer, price FROM Sells WHERE bar = 'Joe' 's Bar' ".
- Access beer and price from each tuple by:

```
while ( menu.next() ) {
  theBeer = Menu.getString(1);
  thePrice = Menu.getFloat(2);
     /*something with theBeer and
       thePrice*/
}
```

PHP

- A language to be used for actions within HTML text.
- Indicated by <? PHP code ?>.
- DB library exists within *PEAR* (PHP Extension and Application Repository).
  - Include with `include(DB.php)`.

Variables in PHP

- Must begin with $.
- OK not to declare a type for a variable.
- But you give a variable a value that belongs to a "class," in which case, methods of that class are available to it.

String Values

- PHP solves a very important problem for languages that commonly construct strings as values:
  - How do I tell whether a substring needs to be interpreted as a variable and replaced by its value?
- PHP solution: Double quotes means replace; single quotes means don't.

Example: Replace or Not?

```
$100 = "one hundred dollars";
$sue = 'You owe me $100.';
$joe = "You owe me $100.";
```

- Value of $sue is 'You owe me $100', while the value of $joe is 'You owe me one hundred dollars'.

PHP Arrays

- Two kinds: *numeric* and *associative*.
- Numeric arrays are ordinary, indexed 0,1,…
  - Example: $a = array(”Paul”, ”George”, ”John”, ”Ringo”);
    - Then $a[0] is ”Paul”, $a[1] is ”George”, and so on.

Associative Arrays

- Elements of an associative array $a are pairs x => y, where *x* is a key string and *y* is any value.
- If x => y is an element of $a, then $a[x] is *y*.

Example: Associative Arrays

- An environment can be expressed as an associative array, e.g.:

```
$myEnv = array(
  "phptype" => "oracle",
  "hostspec" => "www.stanford.edu",
  "database" => "cs145db",
  "username" => "ullman",
  "password" => "notMyPW");
```

Making a Connection

- With the DB library imported and the array $myEnv available:

```
$myCon = DB::connect($myEnv);
```

Function connect in the DB library

Class is Connection because it is returned by DB::connect().

Executing SQL Statements

- Method query applies to a Connection object.
- It takes a string argument and returns a result.
  - Could be an error code or the relation returned by a query.

Example: Executing a Query

- Find all the bars that sell a beer given by the variable $beer.

```
$beer = 'Bud';
$result = $myCon->query(
  "SELECT bar FROM Sells" .
  "WHERE beer = $beer ;");
```

Method application

Concatenation in PHP

Remember this variable is replaced by its value.

Cursors in PHP

- The result of a query *is* the tuples returned.
- Method fetchRow applies to the result and returns the next tuple, or FALSE if there is none.

Example: Cursors

```
while ($bar =
    $result->fetchRow()) {
  // do something with $bar
}
```